DOE F241.3

**US DEPARTMENT OF ENERGY FEDERAL ASSISTANCE PROGRAM**

**FINAL SCIENTIFIC REPORT**

| 1. Award/Grant Number: DE-EE0002882.001 | 2. Project Title: Recovery Act- INP Bioenergy Indian River County Facility |
|---|---|
| 3. Recipient Name: INEOS New Planet BioEnergy LLC | |
| 4. Principal Investigator Mark Niederschulte | |
| 5. Consortium/ Teaming Members <br>• INEOS Bio<br>• New Planet Energy<br>• USDA<br>• DOE<br>• State of Florida<br>• AMEC<br>• KBR<br>• CDM | |

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## Executive Summary

INEOS Bio and New Planet Energy Florida formed a joint venture company called INEOS New Planet BioEnergy ("INPB") in 2009. This venture's intent was to demonstrate at commercial scale INEOS Bio's third-generation technology (the "Bio Process") that converts a variety of lignocellulosic feedstocks into bioethanol and renewable electricity.

In addition to providing the public with a source of environmentally friendly ethanol to meet gasoline blending requirements, the technology is especially advantageous because:

- Greenhouse gas emissions are reduced by 90% relative to gasoline production, a reduction greater than that demonstrated by competing bioethanol technologies.
- The technology is capable of producing ethanol, steam and electric power without consuming external energy.
- The feedstock slate includes those derived from municipal solid waste. Hence, valuable landfill space can be conserved through the conversion of waste into valuable products.
- Renewable electricity is produced as a byproduct and the unit can be designed to feed power to the electrical grid.

INPB applied for and was awarded a $50,000,000 Department of Energy ("DOE") grant in 2009 to support the construction of the commercial demonstration plant. The grant was a cost-sharing arrangement requiring at least 50% equity participation by the grantee. INPB completed construction of the Indian River BioEnergy Center in Vero Beach, Florida in June, 2012. The facility was designed to produce 8 million gallons per year of fuel-grade bioethanol and 6MW of electrical power, with upwards of 2MW exported to the electrical grid. Plant size was chosen as the largest practicable scale to demonstrate individual unit operations and represented tenfold (and greater) increases in processing volumes over previous pilot plant demonstrations. Larger and more economically robust facilities could subsequently be constructed with minimal risk by running multiple process "trains" in parallel.

Construction of the Indian River BioEnergy Center was completed on-time and within its capital budget of $121 million. Initial test runs in 2012 demonstrated that suitable syngas could be generated from wood chips and vegetative waste and that anaerobic bacterial digestion of the syngas could be sustained to make on-spec bioethanol.

The initial test work also revealed several technical issues that needed attention before design production rates and reasonable operational reliability could be claimed. These issues have required corrective efforts and precluded completion of standard performance runs. Responses to the technical issues have extended the planned commissioning/start-up period from 6-months total to now more than 3 years. As a result, this final DOE-required report is being issued before full demonstration of the unit and efforts continue towards solving key operating problems and proving the project's technical design goals.

## Project Description

The Project (INEOS New Planet BioEnergy's Indian River BioEnergy Center) is the first commercial scale facility employing the INEOS Bio "Bio Process" technology. The project broke ground in February 2011 and was completed in 15 months. Utilizing a unique combination of gasification and fermentation processes, the facility is expected to demonstrate key equipment at full commercial scale using vegetative, yard, and municipal solid waste as feedstock. Through a proprietary process, the feedstock is heated to produce a synthesis gas that is cooled and cleaned before being fed to naturally occurring bacteria. These patented bacteria convert the synthesis gas into ethanol, which is purified for use as fuel in the transportation market.

This unique "feedstock flexible" process has been in development for over 20 years with eight years of pilot plant testing. In addition to building their own plants based on the success of this project, INEOS Bio will also explore licensing agreements with third parties to build similar commercial bioenergy plants to supply ethanol and clean energy around the United States and the world.

Once operational, this project will have significant positive impact on the local community. Building and operating the facility provides green jobs in a region with a substantial unemployment rate and redevelops a former agricultural industrial site. The biomass gasification process produces clean energy from a steam turbine, which is expected to run the plant and deliver electricity to 1400 homes in the local community. The availability of ethanol for fuel in the region significantly reduces the costs and environmental impacts of transporting ethanol across the country to fulfill Florida's E10 ethanol standard, while providing energy security to Florida and the nation.

The anticipated completion of this project is a step further towards meeting the RFS2 goal of displacing fossil fuels with 16B gallons of cellulosic biofuels by 2022.The Indian River BioEnergy Center, when at capacity, will add 8 MMGPY of cellulosic ethanol production capacity in the US and renewable power. Successful completion of this project can lead to broad deployment of the INEOS Bio technology globally utilizing a variety of feedstocks.


- 8mmgal/yr cellulosic ethanol
- 6 MW gross power generated
- Vegetative & Yard Waste + MSW
- Strong US, State government partnership
- Ground broken in February 2011
- Mechanical Completion – June 2012
- EPA Registration RFSII – Aug 2012
- Renewable Power Generation – 3Q 2012
- Cellulosic Ethanol Production - 2013
- Installation of HCN scrubber system – 2014

**Figure 1 The facility utilizes a unique combination of gasification and fermentation processes using vegetative and yard waste from the local Indian River County to produce bioethanol and renewable power.**

**Figure 2 Top of picture shows the wind rows of vegetative and yard wastes that were optimized during the course of the project.**

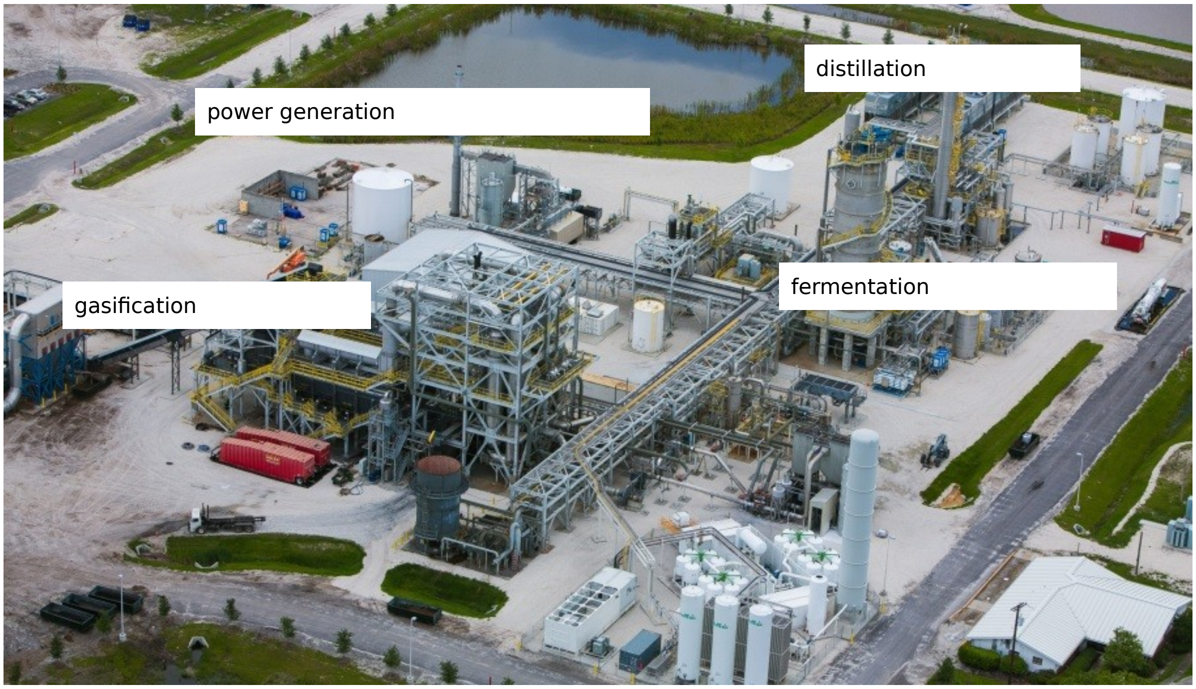



Figure 3 Aerial view of the process areas at the Vero Beach site.

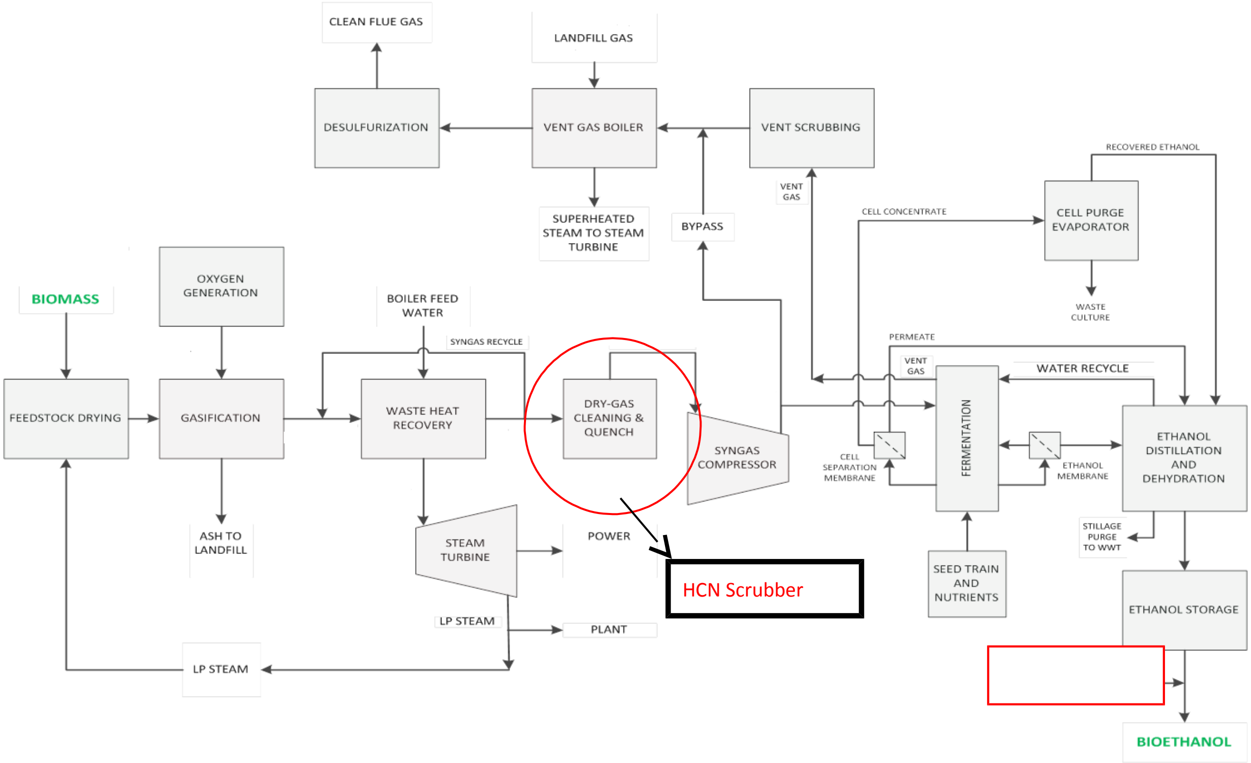



Figure 4

The process flow diagram in figure 4 highlights some of the technology upgrades we have done to the plant since our initial application. We installed an HCN scrubber due to sensitivity of our bio-organism to low levels of HCN. In regards to the denaturant, while producing ethanol at Vero Beach, we discovered our commercial ethanol contains 2% biobutanol that both the Environmental Protection Agency (EPA) and Tobacco Trade Bureau (TTB) approved for use as an alternative denaturant.

*Project Management Approach*

INEOS Bio follows an established stage-gate process for all major projects. The development of projects follows the outline below:

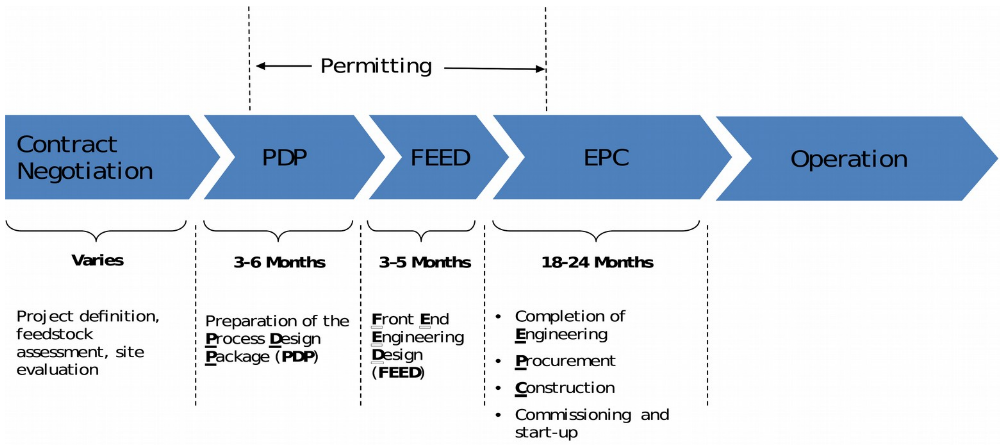



Figure 5

***Stage-Gate Project Schedule***

| | APPRAISE | SELECT | DEFINE | EXECUTE | OPERATE |
|---|---|---|---|---|---|
| | Front End Loading | | | | |
| Goal | Determine Project feasibility & business strategy alignment. | Select the preferred project option(s). | Finalize project scope, cost, schedule and fund project. | Implement project, consistent with scope, cost, schedule. | Evaluate project to ensure performance &ROI |
| | Utilized extensive integrated pilot plant data (40,000+ hours) to define comprehensive material and energy balances for each unit of operation | Utilized focused pilot plant trials, some with vendor support, and EPC contractor expertise to select specific equipment | Utilized site specific feedstock in pilot trials and extensive EPC contractor expertise to optimize the process design, plant layout and equipment vendor selection | Detailed design & construction completed in 20 months | Compare project performance against project objectives, complete PTR |

## Technical Accomplishments/ Progress/Results/Summary

| Milestones |
| --- |
| All Federal, State & local permits received |
| EPA pathway approved under RFS II, RINS generated |
| Generation of Renewable Power demonstrated at 90% capacity and export of excess power to the FL grid |
| Worked with Florida Power and Light to resolve power issues |
| Catalyst poison investigated and identified to be HCN |
| Pilot Plant developed plan to explore different options to address HCN in syngas |
| Design, install and commission the solution to the cyanide issue at commercial scale |

*Project Execution Summary*

| Milestone |
| --- |
| Project constructed on schedule and under budget |
| 1,000,000 work hours on project – zero classified reportable injuries |
| OSHA Classified Rate for project of 0.201/100,000 hrs |
| Key Milestone achieved breaking ground and construction of core plant in 15 months – Feb 2011 – June 2012; |
| DOE Performance Test - March 2016 |

*Technical Performance*

### I. Project Goal Status

The ultimate goal of this project was to demonstrate the commercial viability of the Bio Process. This would be done by constructing, operating and optimizing a demonstration scale bioenergy facility using INEOS Bio's third-generation technology (the "Bio Process") and validating at full commercial scale the economic conversion of several different lignocellulosic feedstocks to bioethanol and renewable electricity. To date, commercial viability has not yet been achieved for the system as a whole. The demonstration plant was successfully built on-time and within budget and has operated successfully for limited periods. Due to its sequential unit operations, the front-end equipment (e.g. feed handling, gasifiers, gas cleaning) has more on-stream time than back-end equipment (e.g. fermentation, ethanol recovery and purification). This has allowed more optimization and improvements to be made to the front-end equipment. While numerous technical advances have been made to improve front-end operations, perhaps the most valuable insight has been gained with the fermenters. When suitable syngas has been provided to the fermentation section, commercial scale fermentation was robust and confirms the viability of this new application.

Initial test work revealed several technical issues that needed attention before design production rates and reasonable operational reliability could be claimed. These issues have required corrective efforts and precluded completion of standard performance runs. Technical issues include (non-exhaustive list):

- Electrical reliability from Florida Power and Light ("FPL") has been poor. While the facility is designed to function with interrupted power from FPL, it has not achieved its own reliability level that compensates for constant disruptions from the FPL supply. Several corrective actions have been completed and additional options are still being reviewed. This situation is considered more a function of the INPB project location than a technical limitation of the process.
- Higher amounts of water in the vegetative waste than planned. Given the massive feedstock storage and handling scope for this project, this has largely been a learn-as-you-go process to optimize the feedstock handling (e.g. size preparation, aging, pile protection, etc.) and to compensate for the humid Florida conditions. Feedstock moisture control has now advanced as a Six-Sigma project to further improve this variable.
- The syngas baghouse for cleaning the syngas stream has been problematic. This includes operational issues with injecting the cleaning agent in the humid Florida environment, as well as its operation when the gasifiers are not running consistently. Optimization of this operation has also progressed to a Six-Sigma project.
- The gasifiers have had mechanical failures. This is not totally unexpected, as the gasifiers were considered to be a notable scale-up risk and repairs for such equipment typically require lengthy downtimes.
- There have been higher amounts of cyanide in the syngas than planned. Cyanide in the syngas needs to be minimized to avoid excessive deactivation of the anaerobic bacteria in the fermenters. An HCN scrubber was designed, installed and commissioned in 2015 to remove cyanide, which significantly helped the operation.

Responses to the above items and others of similar nature have extended the planned commissioning and start-up period from 6-months total to now more than 3 years. As a result, when combined with the current low ethanol price environment, the Indian River BioEnergy Center will not achieve its financial goals because of the extended commissioning/start-up timeframe and the cost of corrective actions. However, the expected capital investment for a new facility should increase only modestly as a result of the additional HCN scrubbing step. Most other lessons-learned can be incorporated during design with minimal cost differences. While ethanol value will always play a role in achieving positive economic returns, low cost feedstock provides an attractive incentive and advantage for this technology over most other biomass-based options. Additional economic benefits are expected for larger scale projects.

**Specific Objectives**

- Construct and operate an 8 million gallon per year demonstration scale bioenergy facility.
- Demonstrate key equipment at full commercial scale using wood and vegetative lignocellulosic wastes as feedstocks.

- Optimize the operation of the unit to determine the actual throughput for each of the key pieces of equipment, the optimal economic operation point and the overall stability and robustness of the equipment and the process.
- Obtain steady-state operational and emissions information and develop the necessary technical and economic performance data to validate the design and economic assumptions.

**Specific Objectives Status**

Construct and operate an 8 million gallon per year demonstration scale bioenergy facility. **(In Progress)**

The Indian River BioEnergy Center in Vero Beach, Florida was constructed on-time and within its approved capital budget of $121 million. Mechanical completion occurred in June, 2012. The plant was commissioned and has been attempting to demonstrate its various design capabilities since then.

While the BioEnergy Center has been operated in its entirety, this specific objective will not be complete until a Facility Performance Test Run ("FPTR") has successfully concluded.

Prior to the FPTR, system specific Performance Test Runs ("PTR") are being performed to identify any issues that may prevent a successful FPTR. A number of engineering modifications have been identified that will be covered in subsequent sections of this report. A Performance Test was completed to demonstrate the capabilities of the facility at the end of the DOE project performance period. This Performance Test was completed under the supervision of DOE's Independent Engineer.

Demonstrate key equipment at full commercial scale using wood and vegetative lignocellulosic wastes as feedstocks. **(In Progress)**

In the upcoming months, equipment rates will be gradually increased using vegetative feed, followed by RDF feed.

Optimize the operation of the unit to determine the actual throughput for each of the key pieces of equipment, the optimal economic operation point and the overall stability and robustness of the equipment and the process. **(In Progress)**

Wood and vegetative lignocellulosic wastes have both been used during the 3+ years of gasifier operation. All equipment has been utilized and demonstrated at some level.

System specific PTRs have identified a number of items requiring engineering modifications prior to conducting the FPTR. By functional classification, these include:

**Gasifier Capacity**

- New equipment was designed and installed to reduce gasifier overpressure conditions that initially limited throughput.
- An additional feed-forward fan was designed and installed to ensure adequate syngas is sent to fermentation.

**Syngas Quality**

- A higher level of air ingress into the gasifiers has caused higher than design $N_2$ levels. This has been partially addressed by designing and installing new seals.

**Fermentation**

- The fermenter does not run efficiently at the original design pressure and will be operated at a lower pressure. This required modification of the fermenter offgas lines to enable supply to the Vent Gas Boiler.
- An additional pump and piping modifications were required for the fermentation membrane system to improve operation.
- Designing and installing a new HCN scrubber upstream of fermentation. Cyanide levels in the syngas have been drastically reduced.

**HCN**

The gasification of vegetative matter produces low levels of hydrogen cyanide (HCN) in the syngas, depending on the operating conditions in the gasifier. In general, higher gasifier temperature results in lower HCN concentration. However, operating at very high temperature may lead to equipment unreliability, poor availability and high maintenance costs. It had been determined through testing at the INEOS Bio Pilot Plant Research facility in Fayetteville, Arkansas that minimizing the HCN concentration in the syngas is needed for the fermentation processes at the Vero Beach plant to reliably meet the project design targets. A three tower gas scrubbing system with high water recycle rate has been designed:

- Tower 1 (Syngas HCN Scrubber) will be a fixed-bed, counter-current flow, packed tower. Syngas will enter under the bed and will mix with the scrubbing water that is sprayed and evenly distributed over the top surface of the packed bed. The scrubbing water is recycled back through the system.

- Tower 2 (HCN Stripper) will be the same basic design. A fixed-bed, counter-current, packed tower. The HCN will be stripped from the water stream by a blown air stream and the HCN containing air will be sent to Tower 3 for cleaning. Cleaned water is returned to Tower 1.

- Tower 3 (Air HCN Scrubber) will absorb the HCN from the air stream into the water stream, also using the same fixed-bed, counter-current flow design used in Towers 1 and 2. The HCN free air (95% or greater HCN removal, as guaranteed by the vendor) will be discharged to atmosphere from the top of Tower 3. The HCN containing water from Tower 3 will be treated in-situ with a bleach and caustic solution to neutralize the dissolved HCN in the water. The treated water will then be disposed of normally as with other plant waste water in the site direct injection well (DIW).

To summarize: The purpose of Tower 1 is to scrub HCN from syngas. The purpose of Tower 2 is to scrub HCN from the scrubbing water used in Tower 1 to allow high water recycle rates, and the purpose of Tower 3 is to remove HCN from the air used in Tower 2 before releasing the air into the atmosphere. Tower 3 employs a recirculating caustic / hypochlorite system to absorb the HCN from the air.

**Quench Tower Fouling**

- Quench Tower system suffers two main operational issues:-
  - Collection of rust particles blown forward from the upstream syngas pipework. Fouls the quench, pump suction filters, exchanger and water nozzles.
  - Precipitation of elemental sulfur. Coats the plate frame exchanger and reduces flow and heat transfer. Also can foul the quench tower distribution pipe work.
- On-Line Mitigation Measures
  - Change out the in-line strainers regularly. Wash out quench tower fully during outages. Complete.
  - Rumbling the exchanger and distributor with nitrogen clears the fouling. Integrated into SOP.
  - Proposal being developed for additional filters to remove rust particles.

**Gasifier Reliability**

- Slag formation in the gasifier throat area has terminated some of the runs. Operation procedures have been modified and engineering controls added to minimize slagging.

**RELIABILITY ISSUES – Major Outstanding Issues**

| Issue | Impact | Status/Proposed Solution |
|---|---|---|
| Fan seal performance | Oxygen ingress | New seal designs under review. **2016 completion** |
| Power trips | Loss of gasification/fermentation | Improvements implemented and tested |
| Dry gas scrubber system reliability | Poor addition of scrubbing medium resulting in downstream corrosion problems | New system design under review. **2016 completion** |
| Corrosion of syngas system. | Bag house and pipework | Replace bag house and pipework with alternative metallurgy; improve scrubber system operation |

| **Plant Reliability Issues**<br><br>Historical problems preventing steady and continuous operation | **Current Status and Plan**<br><br>**Steady operation can be sustained but at reduced efficiency, life and/or capacity** |
|---|---|
| Feed stock high moisture levels | Six-Sigma Project to optimize drying process |
| Quench Fouling | Appears to be manageable. |

| **Plant Reliability Issues** | **Current Status and Plan**<br>**These items are believed resolved but long run required to demonstrate.** |
|---|---|
| Primary Heat Exchanger Fouling | Root cause indicates cessation of feed to initiate the fouling due to loss of temperature and flow. Improved process control and operating guidelines implemented |
| Syngas Bag House Pressure Drop | Six-Sigma Project. Improvements to start up and shutdown procedure. Results during recent campaigns appear good. |
| Drier fines removal and collection | Compactor ordered to allow full automation of the fines collection process. -<br>Complete and under testing. Early results very positive. |
| Electrical Supply Reliability | Backup generators in AUTO start status<br>All tested in island mode.<br>All other site actions complete. |

## Performance Test Run (PTR) Status

Design of the new expanded has not yet begun, but engineering and operational learnings are being documented so that improvements will be readily incorporated in any new facilities.

Obtain steady-state operational and emissions information and develop the necessary technical and economic performance data to validate the design and economic assumptions. **(In Progress/Planned)**

The FPTR will use existing plant instruments. All measurements, flows, temperature, etc. will be at an accuracy level typical of a production unit. The instrumentation and equipment currently in place at Vero Beach will be calibrated and maintained as outlined by the vendors' recommendations and updated through regular plant preventative maintenance systems.

Several of the instruments are adjusted for temperature, steam, water content, syngas quality, etc. These adjusted values and factors have been added into the DCS system.

Key FPTR instruments for which commercial grade accuracy is required include:

- Ethanol flow to tankers
- Natural gas import
- Oxygen import
- Electrical power export/import
- Feedstock weighbridge (if used)

The following information will be validated at commercial scale (as represented by equipment sizing of the demonstration plant):

- Safety and environmental performance
- Variable and fixed cost performance
- Plant availability
- Equipment reliability
- Syngas quality
- Feedstock utilization (including RDF)
    - Gallons per dry ton
    - MWH power produced per dry ton
- Fermenter yield (gallons of ethanol per $ft^3$ capacity)
- Fermenter cell purge rate
- Water usage per gallon of ethanol produced
- Electrical power export

As of this report date, the FPTR has not been completed. Some corrective actions were identified earlier in this report. Individual unit operations have been operated at varying levels and have provided insight on many of the operational targets listed above. Broadly speaking, performance and reliability improvements have to be demonstrated in the feedstock handling, gasification and syngas clean-up areas to commercialize the Bio Process. This is based on demonstrated or expected performance of all unit operations without major additional capital investment.

Operational performance issues have been compounded by mechanical and production site issues unrelated to the technology. Major equipment failures due to vendor errors caused significant downtime. These items were repaired and corrected by the vendors.

Florida Power and Light's plant electrical feed has been unreliable and has forced numerous shutdowns. While the plant is designed to operate in "island mode" by generating its own electric power, it needs to first achieve steady state operation at close to design rates. The extended commissioning phase has not progressed to the point where the full plant has reached the steady state level.

Moisture levels of the mulch feedstock have consistently been higher than the design level intended for feed to the dryers. Progress has been made towards reducing this moisture level through better management of the feedstock handling operation, including initial processing (receipt, grinding, screening, field placement), aging and final staging of the feed prior to use. Six-Sigma techniques have been applied in this regard. Despite this progress, higher than design moisture levels for mulch will likely be the norm. Although the dryers are working satisfactorily, they cannot achieve the design moisture level intended for the gasifiers. The wet feedstock generates higher water vapor in the gasifier, reducing the syngas quality to the fermenter. This also reduces the bone-dry feed quantity sent to the gasifiers.

Air ingress into the syngas lines, which operate at a slight vacuum, continues to impede operation. The fermentation bacteria are anaerobes and their exposure to oxygen levels needs to be kept to very low levels. Two key features should be considered for future gasifier designs to limit the air ingress: 1) minimize the number of line connections through simpler layout and/or maximized welding and 2) using minimum 150# flange connections and appropriate gasketing for the connections that remain.

Gasifier operation has also been impacted by slag formation in the throat area that causes excessive pressure drop and loss of control. Progress has been made through equipment modifications and operating window modifications.

Gasifier operating temperature has been thoroughly investigated and modified accordingly to balance syngas quality and equipment reliability. While higher temperature would aid syngas quality (including destruction of poisonous HCN), lower temperatures have proven best for refractory life inside the gasifiers. Operational temperatures thus established represent a compromise, and hence required that an HCN scrubbing system be added to the syngas treatment. HCN scrubbing is considered an established technology and has proven quite successful, but is also a contributor to the extended commissioning period at the Vero Beach site.

While significant progress has been made in the feedstock and gasifier areas, work remains towards achieving better quality syngas and subsequently producing more ethanol. At present, the $CO/H_2$ levels in the syngas are less than design levels. This is primarily due to higher water and nitrogen levels from feedstock and air infiltration issues. Apart from corrective actions for these two issues, better performance can also be expected when gasifier reliability allows more extended operation and optimization.

Syngas cleanup continues to be an occasional problem area, although encouraging progress has been made. This is largely a water management issue, so as to prevent liquid water from interfering with injection of scrubbing medium.

At this point in the evaluation and as just described, multiple limitations extending from the feedstock supply to the syngas cleanup suggest that the demonstration plant at Vero Beach will produce at lower than design levels even if it is operated reliably at 8,000 hours per year. Efforts continue in improving performance of these various components towards the ultimate design goals. The upcoming FPTR is part of that effort and should better define actual capabilities as a more extended performance run is achieved.

The remaining fermentation and recovery/purification units have not been operated as much as the upstream operations due to their dependence on the generation of the syngas feed. Of the two downstream units, fermentation is the only new technology, but one that is critical to the successful demonstration of the Bio Process.

Fermentation performance has largely met design expectations when good quality syngas has been provided. The fermentation process is considered largely validated by its successful operation in these commercial scale fermenters. This key component of the Bio Process gives encouragement of the process' economic viability once the more mechanical issues of the upstream processing are corrected.

Ethanol recovery and purification is considered standard technology and the demo plant has demonstrated that good quality ethanol can be produced. It still needs to be demonstrated at higher production rates, which will occur as upstream operations become established.

Incorporate the knowledge from Phase I in to the base technology design by 1) revising equipment specifications, 2) updating process and instrumentation diagrams and 3) updating the Standard Operation Procedures. The improved design will be used to prepare a capital cost estimate, budget and pro-forma economics and business plan for Phase II expansion of the facility to an ethanol production capacity of 50 million gallons per year. This design will also be used as the design basis for other facilities as and when viable projects are developed. Original intent was to build 50 MMGPY facility at Vero Beach (adjacent to municipal waste facility). Plant size may be limited by feedstock availability, with 50 MMGPY taken as reasonable scale. **(Pending**)

Documentation is being updated as required by standard plant operational procedures (e.g. MOC, HAZOP, P&IDs, etc.). Work is totally focused on maintaining safe operations and assuring that legal and procedural requirements are met at Vero Beach, while subsequently improving the Bio Process and achieving design production levels towards completion of the FTPRs.

Any Phase II and/or commercial work is on hold until the Vero Beach demonstration is satisfactorily concluded. Current demonstration levels do not support advancement of this option. As previously described, however, equipment and operational changes are expected to achieve performance improvements that will support the economic viability of the Bio Process.

**Project Successes**

The Construction of the unit was successful and completed on budget and on time. While the demonstration of the technology is still in progress, the most valuable outcome has been in the production fermenter, with the commercial fermentation proving to be robust. The future plans are to complete the demonstration of the technology in order to confirm the project economics. It is also a high priority to demonstrate conversion of Refuse Derived Fuel (RDF) which INEOS Bio has identified as the largest potential licensing market. Once this can be demonstrated at scale the intent is to license the technology worldwide.

Improvements to date:

- Modified bio-drying operations to achieve lower moisture in feed; still higher than design in the wet season
- Gasifier system operation much more reliable
- Continuing to improve reliability of scrubbing medium addition system
- Continue to work to reduce Air / $N_2$ ingress
- Start optimization process
- Demonstrate long-term stability
- Demonstrate cell separation / water recycle

**Project showstoppers**

The main project show stoppers have been the power reliability (Joint with Florida Power & Light); with unknown long term effects; feedstock moisture control; Syngas quality improvement; Equipment reliability issues; Unknown scale-up issues in main fermenter due to limited run time; Syngas baghouse (Six-Sigma project); Gasifier throat slagging; HCN accumulation which has been solved through scrubber installation; Equipment failures.

**Project Energy Sources:**

- This process has a very low energy demand with electricity production integral to the process;
- Favorable LCA Score (Est >100% GHG Savings)
- Landfill Gas from Adjacent Landfill
- Future renewable feedstocks include:
    - Biogenic Fraction of Municipal Solid Waste (RDF)
    - Approved Construction & Demolition Waste (C&D)
    - Ground-up tires (Approved European & other region use)

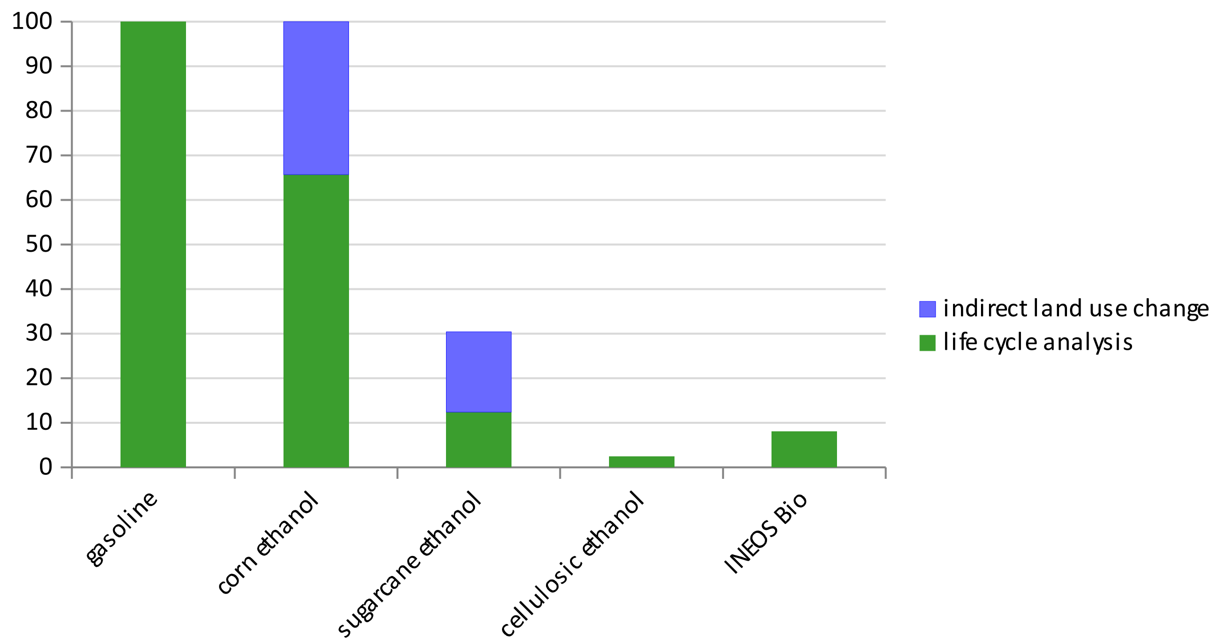



**Figure 6 Relative Carbon Int Relative Carbon Intensities of gasoline and ethanol products, $gCO_2e/MJ$**

Facility Wide Emission Rates, tons per year

| | Annual Emissions (tpy) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOx | CO | SOx | VOC | PM10 | PM2.5 | Pb | Total HAP | Hg | HCl | PCDD/PCDF | Cd |
| Feedstock Handling area | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Paved Road* | --- | --- | --- | --- | 2.87 | 0.43 | --- | --- | --- | --- | --- | --- |
| *Materials Handling Operations* | --- | --- | --- | --- | 1.20E-02 | 1.82E-03 | --- | --- | --- | --- | --- | --- |
| *Shredding and Screening* | --- | --- | --- | --- | 4.72 | 4.72 | --- | --- | --- | --- | --- | --- |
| *Shredder and Screen Engines* | 13.07 | 12.37 | 0.80 | --- | 0.72 | 0.72 | --- | --- | --- | --- | --- | --- |
| *Feedstock Windrows* | --- | --- | --- | 33.38 | --- | --- | --- | --- | --- | --- | --- | --- |
| Emergency Fire Pump Engine | 0.31 | 0.07 | 4.05E-03 | --- | 2.20E-02 | 2.20E-02 | --- | --- | --- | --- | --- | --- |
| Emergency Standby Generator | 0.13 | 0.27 | 1.26E-04 | 0.07 | 2.04E-03 | 2.04E-03 | --- | --- | --- | --- | --- | --- |
| Feedstock Dryers | --- | --- | --- | 33.38 | 3.79 | 3.79 | --- | 5.45 | --- | --- | --- | --- |
| Vent Gas Boiler | 72.09 | 18.29 | 44.98 | 9.33 | 7.54 | 7.54 | 6.28E-02 | 4.85 | 2.20E-02 | 4.76 | 4.08E-06 | 6.28E-03 |
| Distillation | --- | --- | --- | 0.46 | --- | --- | --- | 0.18 | --- | --- | --- | --- |
| Syngas Flare | 2.17 | 40.62 | 22.41 | 2.65 | 0.92 | 0.92 | 9.56E-03 | 4.87 | 3.90E-04 | 4.80 | --- | 1.67E-04 |
| Tank Farm | --- | --- | --- | 1.69 | --- | --- | --- | 5.25E-02 | --- | --- | --- | --- |
| Dry Chemical Silos | --- | --- | --- | --- | 0.66 | 0.66 | --- | --- | --- | --- | --- | --- |
| Cooling Tower | --- | --- | --- | --- | 2.11 | 2.11 | --- | --- | --- | --- | --- | --- |
| Loading Area Flare | 7.41E-02 | 1.39 | --- | 1.66 | 2.00E-02 | 2.00E-02 | --- | 5.42E-04 | --- | --- | --- | --- |
| Miscellaneous Tanks | --- | --- | --- | 0.25 | --- | --- | --- | 4.31E-03 | --- | --- | --- | --- |
| Total | 87.85 | 73.00 | 68.20 | 82.88 | 23.37 | 20.92 | 7.24E-02 | 15.41 | 2.24E-02 | 9.56 | 4.08E-06 | 6.45E-03 |

**Table 1 Emissions Table from Air Permit**

- Minor source for regulated criteria pollutants; <100tpy
- Minor source for hazardous air pollutants (HAPs); <10tpy for each, < 25tpy total
- The project in Vero Beach has undergone extensive environmental analysis and permitting at the local, state and federal level. This includes air permitting from the Florida Department of Environmental Protection (FDEP). The link to the air permit and FONSI:

- Link to INEOS New Planet BioEnergy Facility Air Permit: http://www.dep.state.fl.us/air/emission/bioenergy/indian_river.htm
- Link to USDA Finding of No Significant Impact and Environmental Assessment: http://www.rurdev.usda.gov/rhs/pss/Assessments/INEOSFONSIandEA.pdf

Actual Emissions – Annual Operating Reports 2014-2015

| Pollutant | 2015 Actual (TPY) | 2014 Actual (TPY) |
|---|---|---|
| CO | 8.945487 | 8.038859 |
| CPM | 1.390000 | |
| D/F | 0 | 0 |
| H027 | 0 | 0 |
| H106 | 0 | 0 |
| H114 | 0 | 0 |
| H2S | 0.000010 | 0.000010 |
| HAPS | | |
| NOX | 18.003872 | 17.222836 |
| PB | 0 | 0 |
| PM | 2.186914 | 1.079732 |
| PM10 | 2.346105 | 1.498202 |
| PM2.5 | 2.335391 | 1.494870 |
| SO2 | 6.510523 | 2.981301 |
| VOC | 10.275722 | 7.730519 |

Table 2

# Feedstock

Feedstock Supply

- Vegetative/Yard waste,
  - Palm fronds (35%), woody vegetation (45%), grass clippings (10%), other (10%)
- Agricultural Waste - Citrus
- No new standards or quality controls on vegetative waste
- Wood for Start-up – 5 varieties tested so far (oak, loblolly pine, slash pine, longleaf pine, citrus). In general, any dry wood works.
- Refuse Derived Fuel (RDF) trial (anticipated 3Q 2016).

Feedstock pre-processing required

- Process modified to improve bio-drying performance
- Size reduction via shredding and screening

Feedstock supply chain

- Diverted from adjacent IRC landfill and other local generators of vegetative waste (landscape companies, other municipalities, etc.)
- Delivery using existing logistics infrastructure
- Delivery by individual: Residents of Indian River County (IRC) have the option to deliver their yard waste directly to our site. The site has a designated residential receiving area where all deliveries are received, inspected, and sorted by a ground spotter before storage.

- Delivery by commercial truck: Commercial trucks are directed to receiving piles in the commercial receiving area. A loader operator inspects and sorts each delivery then pushes the acceptable feedstock to build the storage piles.
- Windrow storage: The un-shredded material is stored in open aging windrows. The windrows are built in a manner to optimize bed porosity. The open and porous windrows allow the material to lose some of its moisture before shredding and screening.
- Grinding and screening: A low speed and high torque shredder is used to reduce the size of the material. This type of shredding equipment was selected to minimize fines byproducts (material sizes < ¼ inch). After shredding, the material goes to a three-way star screener to remove fines and oversize particles from the desired feedstock product.

Feedstock storage capacity

- Bio-drying and finished products are stored in uncovered windrows
- Total approximately 30 days
- Covered building at feedstock drier conveyer approximately 1 day

Estimated available feedstock volumes and delivered cost

- We are paid $14.50 for the Indian River County material we use in the unit, and $16.87 from neighboring Martin County.

## Marketing Plan for Renewable Fuels

There are two major terminals within 100 miles of facility. Florida has an 800+ mgy market and our facility will represent <1% of the market. Off-take for facility is currently with INEOS Bio Marketing & Trading with other interest from major oil companies. There is continued interest from new E-85 Flex Fuel Stations as the infrastructure becomes built-out in Florida as well as opportunities to continue supplying fuel for the EPA Green Racing series or other "Green" races in the future.

**Co-products**

- Power
    - 2.96 cents/kWh (avoided cost)
    - Interconnection agreement w/FPL
- Ash (Non-hazardous)
    - Mixed with fines for Landfill cover
    - Potential for land application

Approvals

The facility has received all necessary approvals from the US EPA for the production and sale of cellulosic ethanol from multiple feedstocks including vegetative, yard, agricultural and wood waste. The process produces approximately 2% Butanol/Higher Alcohols that are blended back into the ethanol. This "natural denaturant" has been approved by the TTB and EPA, resulting in a more pure bio-product and effectively backing out fossil fuel denaturant.

Automotive Acceptance

- Engine Testing completed by multiple external parties

- Testing party reports that ethanol produced by this method does not have lignin-type issues identified with other processes.
- Ethanol can be used as an effective octane-boosting fuel additive or as a stand-alone fuel.
- E10 is approved for use by every major automaker in the world.
- E15 has been approved for 2001 and newer vehicles
- E85 is designed for use in Flex-Fuel Vehicles (FFVs) only.

ASTM
- Product meets/or exceeds ASTM D 4806-09 for fuel grade ethanol
- Product has a high degree of stability, use of corrosion inhibitor used in traditional corn ethanol does not seem to be needed due to the absence of unfavorable by-products in our ethanol

## Environmental Benefits

The INEOS Bio Bioenergy technology can efficiently convert almost any carbonaceous material into clean bioethanol and renewable electricity. It delivers high energy efficiency and is capable of also producing such co-products as electricity and process steam. The INEOS Bio Process is capable of producing ethanol and electric power for export without consuming external BTUs. When using a waste biomass derived feedstock, as will be done for this project, the INEOS Bio Process delivers greenhouse gas emission reductions of 100% (vs. gasoline) and generates superior economic returns when compared to alternative processes. The entire process – using waste products for feedstock, significantly reducing air emissions, producing ethanol for clean fuel use, and generating renewable electricity and other byproducts – represents major environmental, greenhouse gas reduction and energy security advantages. Emissions of regulated pollutants and criteria pollutants from the plant are anticipated to be less than “major” source thresholds established by the US EPA as demonstrated at our Vero Beach Facility.

**Life Cycle Analysis (LCA)**

Eunomia Research and Consulting has carried out an independent GHG assessment on the INEOS Bio Process for organic wastes. The conclusions are: The best use of separately collected green waste (grass cuttings, hedge trimmings, etc.…) is bioethanol production and power generation in the INEOS Bio Process. The bioethanol delivers 100% GHG savings vs. gasoline. The INEOS Bio Process outperforms both aerobic (windrow) composting and biomass combustion for heat and saves 0.42 tons of CO2eqv per ton of waste treated. (Independent studies by Eunomia, table below). Further LCA analysis will be completed once Vero Beach is fully operational.

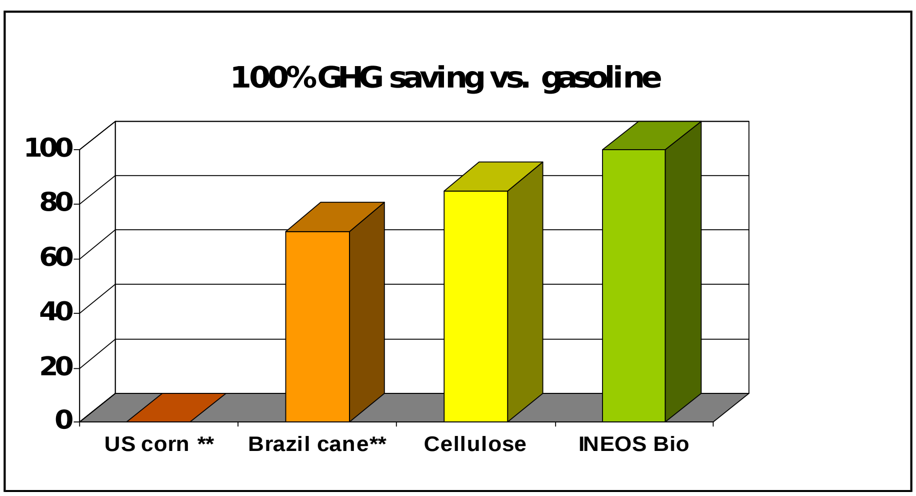



Figure 7 Independent Study by Eunomia

Economic Sustainability: INEOS Bio technology provides access to low-cost feedstocks

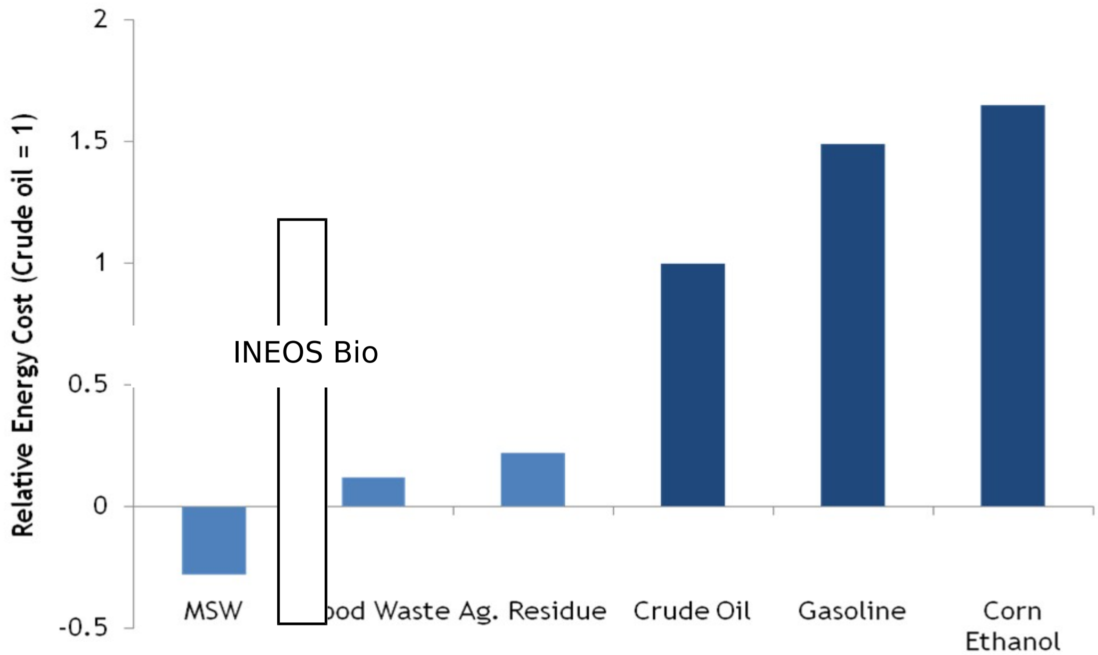



Figure 8 Sources: EIA, USDA, IA State

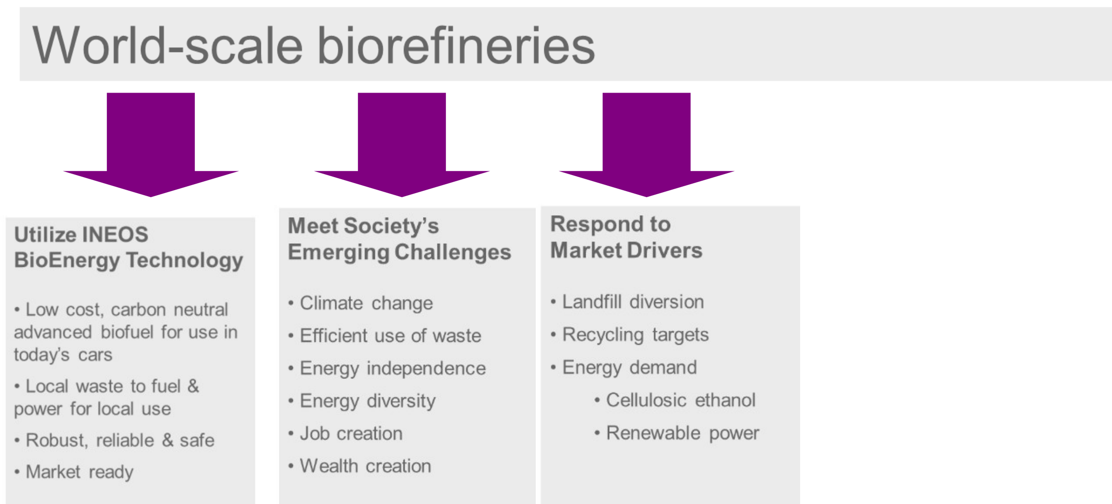
**Relevance - Carbon Neutral Advanced Biofuel from Waste**

| Waste to bioethanol with INEOS Bio Technology | GHG Saving vs. Gasoline |
|---|---|
| Vegetative Waste | 120% |
| Post-recycled Municipal Solid Waste | 80 - 90% |
| Waste wood | 125% |
| 50:50 Garden & Food Waste | 110% |
| **Indian River Bioenergy Center expectation** | **105%** |

- **GHG savings exceeds RFS2 threshold target of 60%; One gallon saves ~5 pounds of $CO_2$ *vs.* gasoline**

This process demonstrates true feedstock flexibility using a combination of biomass gasification followed by a robust fermentation system. This process is energy efficient; produces ethanol *and* power with high energy efficiency than the commercially available technologies (WTE). It is also one of the most economic with the capability of processing negative cost feedstocks. It also meets the meets toughest sustainability criteria.

**Meeting Key Societal Challenges and Market Needs**




This process produces a very low cost, carbon neutral biofuel that can be used anywhere to contribute to energy security and independence. A truly sustainability solution that meets economic criteria – affordable – social criteria – jobs, security, mobility – and environmental criteria – reducing harmful impact on environment.

## Economic Benefits

*Local Content of Material and Labor*

The Vero Beach, FL project re-developed an idle agricultural processing facility next to a landfill into a next generation bioenergy facility using waste from the surrounding communities. In the process, the project created over 400 jobs in construction, engineering, equipment procurement and manufacturing and service jobs related to the project in site development and local legal and environmental permitting resources.

The local content of material and labor included:

- Local legal and environmental services for permitting and site development;
- Local construction sub contracts for site demolition, restoration, preparation and construction and build-out of the facility;
- Local feedstock processing providers;
- Local landscaping, security, and other services;
- Local training through one of the FL State Colleges;
- Local housing and restaurants for workers, visitors, temporary & full-time personnel;

- Local job fairs & hiring of permanent positions at the facility. 2/3 of the permanent positions have been filled with local candidates;
- Local contracts and spending of over $25 million to the local economy during site development and construction;
- Over 90% of the equipment is from U.S. manufacturers;

The Vero Beach facility has 55-60 permanent employees – 2/3 hired from the local area. The jobs bring an annual boost to the local payroll of more than $4 million per year in an area that was experiencing 15% unemployment when the project started (top 25 highest unemployment in the U.S.). The jobs are new clean-tech type jobs in an area which is historically more tourism and real-estate focused. One third of the new permanent jobs meant relocation to the area by new families and the ancillary effects to housing, property taxes, and spending in the local economy.

The key competitive advantages of the INEOS Bio Process include:

- <u>The feedstock flexibility</u> of the INEOS Bio Process enables almost *any community in the U.S.* to manufacture a portion of its own road transport fuel and generate power from the biomass and wastes it generates. Wherever there are people, wastes are generated and transport fuels are needed. Every community of any size in the U.S. could potentially have its own INEOS Bio Process plant or plants.

- <u>Practical and sustainable</u> -- The use of feedstock otherwise destined for landfills assists municipalities struggling with both the cost and logistics of waste disposal and extending the life of the existing landfill. The use of landfill materials for the thermochemical production of ethanol also will eliminate the formation of landfill gas (methane) that is 21 times more damaging to the environment than $CO_2$.

- <u>Rapid, continuous conversion</u> - The entire process, from the time the waste material enters the gasifier to the delivery of finished ethanol, takes approximately 7-10 minutes. By comparison, corn and sugar cane and other batch production processes require 45-55 hours. Combined with the use of waste streams as feedstock, this efficiency dramatically reduces ethanol production costs.

- <u>Robust biocatalyst</u> – over 20 years of experimentation with the INEOS Bio microorganism in the laboratory and pilot plant has demonstrated good productivity with high tolerance to syngas impurities, with fermentation times of only a few minutes.

- <u>Lower capital costs</u> - The rapid biochemical reaction and relative simplicity of the INEOS Bio Process enables its commercial plants to be smaller and more compact, and thus achieve lower construction costs per gallon, when compared to alternative next generation ethanol technologies.

In summary, the Indian River BioEnergy center is a world-class technology built in record time, safely, and under budget. This was accomplished with the use of the Integrated Pilot Plant facility, located in Faytetteville AR, to aid in the design, optimization, and scale-up – including continued use in further plant optimization & gaining knowledge during commissioning. INEOS has mitigated risk through experienced team and well-known constructors and equipment providers. Moving forward we will continue to focus on safe operations, optimizing the technology, and debottlenecking the plant to achieve full production capacity while demonstrating additional waste feedstocks at commercial scale to help deploy this technology globally. As stated in the report, commercial work is on hold until the Vero Beach demonstration is complete and fully operational. Equipment and operational changes are expected to achieve notable performance improvements that will help support the economic viability of the INEOS Bio Process.

## Appendix A - Thermal Conversion Technology Overview

The INEOS Bio Process technology is a hybrid technology combining thermo-chemical conversion and bio-chemical catalysis to produce cellulosic bio-ethanol and renewable power. The process may be broken down into 6 primary steps:

1. Feed reception and drying
2. Gasification
3. Syngas heat recovery (to generate renewable power) and gas clean up
4. Fermentation (bioethanol production from syngas through biological process)
5. Filtration, distillation, and dehydration (bioethanol recovery and purification)
6. Renewable power generation

In addition to the main steps described above, the plant includes ancillary systems such as the process sewer and chemical additives systems, culture storage, handling equipment, and intermediate tankage.

The entire process is simple and well defined, and capital and energy costs are minimized. The combination of gasification and fermentation processes overcomes the significant challenges faced by other lignocellulosic ethanol processes (such as pre-treatment of the lignocellulose feedstock, hydrolysis to fermentable sugars, and fermentation of pentose sugars) by breaking complex molecules into CO, $H_2$ and $CO_2$, and then building them back efficiently into a single product, ethanol. Heat integration usefully employs the heat energy generated during gasification for the distillation step and power generation while the rapid synthesis of ethanol at the ambient temperature and low pressure of the fermentation step overcomes one of the primary disadvantages of most biological processes, which is a slow fermentation rate.

As the feedstock used is predominately biomass rather than fossil carbon, the carbon dioxide released from the process is mostly biogenic and does not contribute to global warming. The commercial INEOS Bio plants are designed to be safe, simple, robust, reliable and scalable. Throughout, established and proven technology components are used to control and minimize all emissions streams to air, water and land.

Step 1: Feed reception and drying

The INEOS Bio Process technology is feedstock flexible. A wide range of carbon materials, including biomass waste, can be converted efficiently into bioethanol and renewable power. The use of waste is attractive for production cost reasons, and allows small scale plants to be commercially attractive. However, non-waste biomass feedstocks can equally be used to produce bioethanol. These include agricultural, vegetative and forestry residues and products, energy crops and biogas. Both prepared and unprepared organic waste from household, commercial and industrial, construction and demolition and trade waste sources can be received. Appropriate pre-treatment can either be located remotely or on-site. Prepared organic waste includes:

1. Waste prepared through mechanical techniques including; shredded waste wood, oversize compost mulch, and organic construction, demolition and trade waste

2. Waste prepared through mechanical and biological treatment (MBT) processes including; refuse derived fuel (RDF) and solid recovered fuel (SRF)

3. Waste prepared through mechanical heat treatment (MHT) processes including densified refined biomass fuel (RBF).

Drying can be achieved through using low grade heat from the gasification process, or through bio-drying, or a combination of both.

The waste treatment process for municipal solid waste (MSW) and commercial and industrial (C&I) waste can be co-located with the INEOS Bio plant. MSW can be received on site, treated through material recycling facility (MRF), MBT or MHT processes and supplied directly to the INEOS Bio plant. The INEOS Bio Process technology supports high recycling rates as recyclable materials can either be separated and collected at source, or extracted through the mixed waste pre-treatment process. The recycling of metals, glass, and plastics can be maximized and the efficient use of biodegradable waste as a resource can be optimized by incorporating the INEOS Bio Process technology into an integrated waste management solution.

Step 2: Gasification

The gasification step provides the process with its feedstock flexibility. Unlike conventional first generation bioethanol technologies, which use food crops, or the emerging cellulosic fermentation technologies, which can convert cellulose and hemi-cellulose but not lignin, the INEOS Bio gasification process enables all of the biomass to be used for biofuel production.

This ability to use the entire feed material for bioethanol production through gasification provides important benefits such as; (a) higher yields of biofuel from each ton of biomass than is possible from other technologies, (b) the efficient use of lower cost biomass material such as waste, and (c) the separation of biofuel production from food production and land use.

The INEOS Bio gasification process is a two-step, oxygen-blown technology and converts the prepared, dried biomass waste into a synthesis gas comprising carbon monoxide (CO), hydrogen ($H_2$) and $CO_2$ gases. Carbon monoxide and hydrogen gases contain important chemical energy and are the building blocks for the production of bioethanol. Feedstocks of different bulk density, particle shape and size may be mixed together in order to optimize feed rate and minimize entrained air. Upon exposure to the heat in the lower chamber of the gasifier further drying takes place followed by pyrolysis, generating a pyrolysis gas. The pyrolysis gas passes through to the upper chamber where it is mixed with more oxygen, generating more heat from partial combustion. The high temperature and residence time cracks the pyrolysis gases to carbon monoxide, hydrogen and carbon dioxide. No tars or aromatic hydrocarbons are present in the syngas.

Although there are several reactions which take place in the gasifier, the overall gasification reaction of biomass can be approximated as the partial oxidation of carbohydrate (cellulose) as follows:

$$8CH_2O + O_2 \rightarrow 6CO + 2CO_2 + 8H_2 \quad (1)$$

The gasification proceeds in a reducing environment, with insufficient oxygen present for complete oxidation of the carbon present. This reducing environment suppresses the formation of dioxins and furans, and any dioxins or furans introduced with the feedstock would be destroyed at the temperature and reside … nts the escap…

The minerals and other inert material introduced into the gasifier with the biomass are extracted from the gasifier in the form of an ash by chain conveyor from the bottom of a water quench bath. The ash is uniform and has a small particle size compared to incinerator bottom ash thanks to the pre-treatment process. The ash can be recycled into building and other materials or mixed with soils and fines and used for alternate daily cover on the landfill. The composition and quantity of ash extracted is determined by the feed material. A detailed composition of ash will be measured for each feedstock used on each plant.

Step 3: Syngas heat recovery and gas clean up

The hot syngas is cooled and cleaned before being introduced to the fermenter. As the hot syngas leaves the gasifier upper chamber it is passed through heat recovery exchangers to recover the heat as high pressure steam. This is used to generate renewable power for use in the process and for export. After the heat recovery exchanger the syngas passes through a dry scrubber and then a water quench. The cooled, cleaned syngas is compressed to pass it through the fermenter.

Step 4: Fermentation

The fermentation step is at the heart of the INEOS Bio Process technology. The syngas is introduced into the INEOS Bio patented fermentation process, where naturally occurring bacteria combine them efficiently, selectively and rapidly to produce bioethanol. The fermenter is agitated to aid gas-liquid transfer. The INEOS Bio fermentation process takes only a few minutes, compared to 1-3 days for conventional, first generation and cellulosic fermentation processes. The INEOS bio-chemical synthesis takes place at low temperature and pressure and with high yield and selectivity. This high performance, coupled with tolerance to variations in syngas composition and to common catalyst poisons, means fewer process steps, high energy efficiency, low bioethanol production costs and attractive investment returns.

Nutrients are added to provide for cell growth and automatic regeneration of the biocatalyst. INEOS Bio's proprietary combination of microorganism, nutrients, process design and conditions produces bioethanol at industrial quantities and at a commercially attractive and competitive cost. The bioethanol is synthesized according to the following principal reactions:

$$6CO + 3H_2O \rightarrow CH_3CH_2OH + 4CO_2 \quad (2)$$

$$6H_2 + 2CO_2 \rightarrow CH_3CH_2OH + 3H_2O \quad (3)$$

Carbon and hydrogen in the initial raw material is converted into ethanol; with high yields achieved. Combining equations (1) – (3) gives:

$$8CH_2O + O_2 \rightarrow 2.33CH_3CH_2OH + 3.33CO_2 + H_2O \qquad (4)$$

From Equation (4), the maximum theoretical yield of ethanol from biomass is about 135 gallons per dry ash-free ton of material. This is considerably higher than is possible from other cellulosic fermentation processes. One reason for the higher measured and theoretical yields from the INEOS Bio Process is the ability of the INEOS Bio Process to produce bioethanol from the lignin, pentose, protein, and other carbon-containing fractions of the biomass, which are difficult for other biological processes to use. The inorganic fraction and the moisture content are discounted from the feedstock in making yield projections. The energy content of the feedstock is a determining factor on the syngas composition and on the ethanol production rate. Ethanol production is enhanced by higher energy content feeds.

The microbe used in the INEOS Bio Process technology is a naturally occurring micro-organism (i.e. it is not genetically modified). The bacteria efficiently convert the syngas into ethanol and extract the carbon and energy they require for cell division and metabolism directly from the syngas. As the bacterium is anaerobic, the bacteria die upon exposure to oxygen. It poses no threat to humans, animals or the environment. INEOS Bio is only required to follow Biosafety Level 1 procedures when handling the culture, which is the lowest level of safety precautions.

Most of the syngas is converted to bioethanol. The unconverted syngas (vent gas) is combusted to generate additional renewable power. Sufficient heat and power is generated by the integrated process to meet the entire energy needs of the process with surplus available for third party use.

Step 5: Filtration, distillation and dehydration

The fermenter liquid is continuously extracted, filtered to remove the bacteria and nutrients, distilled and then purified by molecular sieve to anhydrous bioethanol, ready for blending and use in cars. The product meets U.S road fuel quality standards and has been certified by TTB and EPA for sale into commerce. Steam generated by recovering heat from the gasification process is used to provide the required heat energy for distillation. Water from the distillation column is recycled back to the fermenter. Water purge from distillation is treated in a waste water treatment facility.

Step 6: Renewable power generation

Renewable power is generated by two means; (a) by recovering heat from the hot syngas and (b) by combusting the vent gas from the fermentation stage of the process. In both cases high pressure steam is raised, which is used to turn a steam turbine to generate electricity. This is the configuration for the facility in Vero Beach, FL.

The INEOS Bio Process is an innovative process technology combining waste feedstock flexibility with high-value, selective fuel and electricity production. The process is a result of almost 20 years of research and development and is currently being demonstrated at commercial scale in Vero Beach, Florida.

The INEOS Bio Process produces fuel grade bio-ethanol and renewable electricity. If integrated into an established industrial facility requiring high-pressure steam, the electricity production can be substituted completely or in part by steam production for export.